Trident Warrior 2013 Opportunistic VHF and UHF Observations

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LONG-TERM GOALS

Utilize signals from emitters of opportunity to (a) evaluate sources of propagation predictions (e.g., numerical weather prediction), and (b) provide real-time refractivity information using EM inverse methods.

OBJECTIVES

Install instrumentation system onboard the Research Vessel (R/V) Knorr to continuously track signal power from several broadcast emitters in the Norfolk / Hampton area of Virginia. Synchronize data streams with the ships position and heading data. Demonstrate ability to infer effective system constant from observations as the utility of the such techniques is often dependent upon not needing precise information about the emitter's characteristics.

APPROACH

The power budget for radio link from a shore site to a ship is

$$P_r = P_t + G_t(\theta) + G_r(\phi) - I - L(r,\theta) \tag{1}$$

where P_r is the received power, P_t is the transmitted power, G_t and G_r are the respective transmit and receive antenna gains, I is the insertion loss and L is the propagation loss. Arguments for terms for bearing from the emitter, relative bearing referenced to the heading of the ship, and range are θ, ϕ and r respectively. We define a lumped coefficient C such that

$$C(\theta) = P_t + G_t(\theta) - I + \overline{G_r} \tag{2}$$

where $\overline{G_r}$ is the mean receiving antenna gain averaged over relative bearing ϕ. This implies

$$C(\theta) = P_r + L(M) - \delta G_r(\phi) \tag{3}$$

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and

$$L = C - P_r + \delta G_r(\phi). \tag{4}$$

where $\delta G_r(\phi)$ is the deviation such that $G_r(\phi) = \overline{G_r} + \delta G_r(\phi)$. A step we will utilize later is to generate an estimated power $\hat{P}_r$ from loss predicted using an EM propagation model. For that the relationship is

$$\hat{P}_r = C(\theta) - L(M) + \delta G_r(\phi). \tag{5}$$

In the instance of relatively high (e.g., $\geq$ 100m) transmitting omni-directional antennas and minimal terrain effects (typical of FM radio stations in the Norfolk area), C can be considered azimuth independent. Many TV transmission systems utilize horizontally polarized directional antennas hence the use of an azimuth-independent value of C needs to be restricted to sectors where the change in gain across the azimuths in the sector constitute a small contaminant.

Within this framework, there are different ways to determine and use the system constant. For instance, the closer we are to a transmitting antenna, the less the potential effect of the refractive environment on the propagation loss will be. In Trident Warrior, that would correspond to making measurements close to shore to calculate C and applying that C to power measurements at greater ranges to calculate L. An alternative for comparing two means of characterizing the refractive environment is to calculate separate value of C corresponding to each information source; i.e., the value C is optimized for each data data source. This is analogous to how refractivity-from-clutter for evaporation ducts [1] works. In RFC, alternative models for how clutter is realized are compared to the observed clutter with the mean value subtracted from both the actual clutter and the models. In the case of comparing data sources to one another, using the optimal C for each data source removes any bias.

WORK COMPLETED

We installed two separate spectrum-analzer-based systems onboard the Knorr. We acquired one bicone (oriented for horizontally polarized signals) and one broad-band monopole (installed for vertically polarized signals) which were installed on the starboard bridge of the Knorr. These were connected via 85' low-loss coaxial cables to pair of spectrum analyzers located in a laboratory space. We utilized the Matlab Instrumentation Toolbox to develop a script that would control and log data from each spectrum analyzer. The spectrum analyzers could sample between 30 to 50 channels each minute dependent upon the configuration specific to the frequency being monitored. We recorded the signal power, noise floor, and the frequency where the peak power occurred so as to aid in discerning noise versus signal versus wrong-signal. In addition, we recorded the spectogram corresponding to each measurement to facilitate further analysis.

A variety of information sources (e.g., "TV Fool," FCC data, etc.) were used to develop a frequency monitoring plan shown in Table 1. A set of post-processing routines were implemented in Matlab that synchronized the power measurements with the ships latitude, longitude and heading. Having these and the emitter locations enable the calculation of the line of bearing from each transmitter to Knorr and relative bearing (in reference to the Knorr's heading) to the Knorr to the transmitters. In addition to the normal data collections, turns-in-place were undertaken where we had the Knorr spin at a rate of 30° - 45° per minutes and run a spectrum analyzer in a time-series mode. This allowed using emitters of opportunity to obtain the receiving antenna pattern of the antenna as it was installed on the Knorr.

Table 1: List of 11 emitters monitored during Trident Warrior 2013 using SSC Pacific's passive monitoring system. The column on the left is the station designator. The remining columns include the latitude, longitude, antenna height and center frequency. The $\sim$ indicates that the height is based on photographs and not precisely known by the authors.

Station	Location	Antenna height (m)	Frequency (MHz)
WNOB-FM	36.55, 76.19W	297m	93.7
WVHT-FM	36.83N, 76.21W	156m	100.5
ORF-VOR	36.89N, 76.2W	8m	116.9
ORF-ATIS	36.89N, 76.2W	$\sim$25m	127.15
LFI-ATIS	36.89N, 76.2W	$\sim$25m	270.1
NTU-ATIS	36.81N, 76.03W	$\sim$20m	317.6
WHRO-TV	36.81, 76.5W	364m	482.31
WVBN-LP	36.76N, 76.12W	81m	494.31
WYSJ-CA	37.08N, 76.45W	97m	500.31
W24OI-TV	36.86N, 75.98W	64m	530.31
NTU-TACAN	36.81N, 76.03W	20m	1200.0

RESULTS

Of the 11 stations tracked during TW-13, five (WNOB-FM, NTU-ATIS, WHRO-TV, WVBN-LP and WYSJ-TV) appear to provide usable data (i.e, a signal clearly above the noise floor and with the correct peak frequency). Two others, WVHT-FM and W24OI-TV may be usable but that will likely require working with their spectrograms. It appears that ORF-VOR, ORF-ATIS, LFI-ATIS and NTU-TACAN will not be usable. Of the usable data, WHRO-TV, NTU-ATIS and WVBN-LP exhibit the greatest sensivity to variations in refractivity experienced during the cruise.

Some preliminary data is shown in Figure 1. The data presented are based on the power measurements previously described and on a subset of the radiosondes launched by the Naval Postgraduate School and Naval Surface Warfare (Dahlgren Division) during TW-13. Range series and time series are shown for WHRO-TV in Figure 1. In the upper plot, the x-axis is the range from the transmitter to the Knorr. The y-axis is the power as measured in dBm. The small green dots are the received power values observed with the spectrum analyzer. The blue dots represent predictions based on radiosondes mapped into received power using Equation 5. The system constant used in the mapping was found via Equation 3 and loss values for all of the radisondes and all of the power measurements at the time of those radisondes. The red dots were produced in an identical fashion except that a standard (0.118 M-units/m) refractivity profile was used in place of the radiosondes. In simpler terms, the blue and red dots represent mean-difference-removed estimates of power based on radiosondes and the assumption of a standard atmosphere respectively. Because the mean is removed, the ability to discriminate one prediction method from the other – i.e., radisondes versus standard atmosphere – rests on which best represents the spatial trend in the data. The same data is used for a time-series in the lower plot.

These displays do not provide a clear discrimination of the radiosonde versus standard atmosphere predictions. It does appear that the trends (with respect to range) were to continue on to 160 km, that discrimination would be in favor of the radiosondes. At this point, however, this analysis is more

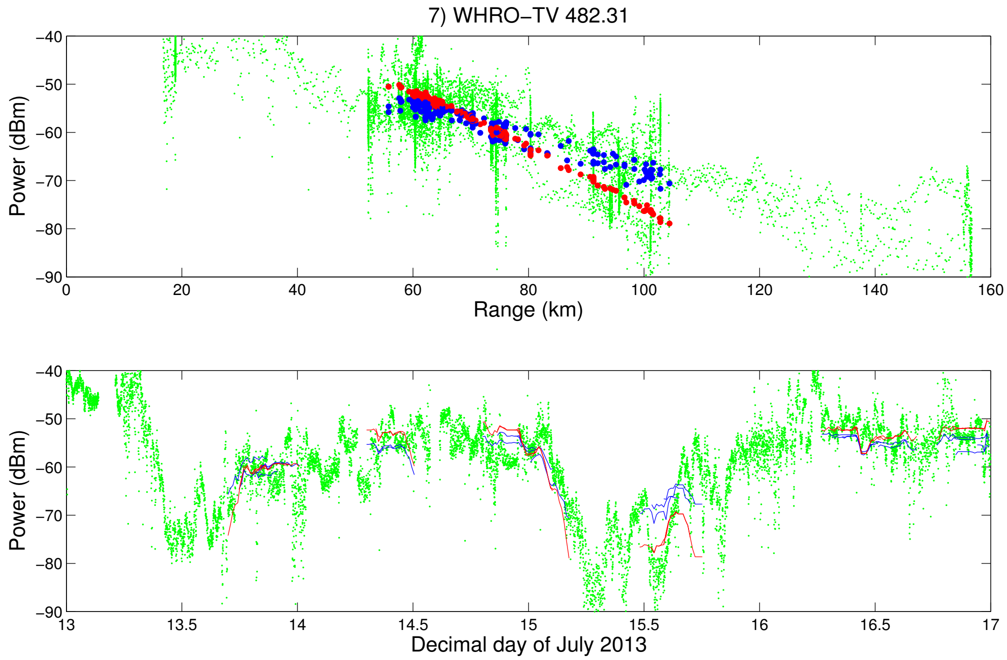

Figure 1: Range-series and time-series of observed and predicted power. The upper plot is power versus range. Small green dots show the observed power (dBm) recorded by the spectrum analyzer corrected for the antenna pattern. The blue dots show power predicted based on radiosondes input to the AREPS propagation model extrapolated forward and backwards 2 hours in time. The mean value of the ensemble of radiosonde-based power predictions has been set to the mean value of the ensemble of power observations over that same time periods. The red dots are similarly produced except that a standard refractivity profile is utilized vice the radiosonde.

indicative of ways to examine the data than a particular result.

IMPACT/APPLICATIONS

This work supports utilization of signals from emitters of opportunity to (a) evaluate sources of propagation predictions (e.g., numerical weather prediction), and (b) provide real-time refractivity information using EM inverse methods.

TRANSITIONS

N/A

RELATED PROJECTS

Refractivity Data Fusion

REFERENCES

[1] Rogers, L. T., C. P. Hattan, and J. K. Stapleton. 2000. ”Estimating Evaporation Duct Heights from Radar Sea Echo,” Radio Science, vol. 35, no. 4, pp. 955966.